THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Decentralizing Statistical Accuracy Control Responsibility To The Ship Production Workforce

U.S. DEPARTMENT OF TRANSPORTATION
Maritime Administration and
U.S. NAVY
in cooperation with
Bethlehem Steel Corporation
Marine Construction Division

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SECTION I

ABSTRACT

This paper presents the organizational structure, methods and results of National Steel and Shipbuilding Company's efforts to decentralize the responsibility of statistical accuracy control from a central Accuracy Control Department to the hourly production workforce. It includes an accounting of the problems and successes encountered during implementation. The results are both quantitative and qualitative in form, including methods for measuring reductions in rework.

During this study, workteams were established in the Hull Fabrication Shop. A three phase methodology was used to introduce the workteams to statistical methods for improving the dimensional accuracy of their products.

The main body of this report was presented at the 1986 Ship Production Symposium in Williamsburg, Virginia in August, 1986. The Addendum covers research activities that took place outside of the time span covered by the paper delivered at the Symposium and includes the implementation of decentralized Accuracy Control in the Assembly area of the shipyard and a summary of results from that decentralization.

Appendix A contains outlines from two training classes developed and presented by the Accuracy Control Department.

Appendix B contains a series of articles from various issues of The Shipbuilder, the NASSCO Company newspaper describing worker/workteam participation in accuracy control activities.

SECTION II

INTRODUCTION

Scope of Problem

International competition and foreign labor rates have put most commercial shipbuilding contracts out of reach for U.S. shipbuilders. This has created a fiercely competitive environment for U.S. Naval contracts. The recent commitment by the U.S. Government to award contracts to the lowest technically qualified bidder has put increased pressure on U.S. Shipyards to reduce production costs as quickly and drastically as possible.

Many shipyards have seen major reductions in outfitting manhours due to downhand and zone outfitting methods. This is an important step, but additional improvements must come from the budgets of the Hull Structural Departments. The commonly recognized methods of increasing steel productivity are:

1. Better designs for production and material cost.

2. Improved detail scheduling and material control.

3. Introduction of yardwide dimensional accuracy control.

Prerequisites for each of these improvements are: standardized processes, product-oriented construction, and well defined manufacturing process lanes.

United States shipbuilders are recognizing that improved quality of interim products will result in increased productivity. At the recommendation of industry publications and outside consultants many U.S. shipyards have formed Accuracy Control Departments hoping to reduce rework and optimize production processes. As they implement accuracy control procedures they are finding that decentralization of responsibility is most effective.

SECTION III

BACKGROUND

Most U.S. shipyards have an Accuracy Control Department, but there is little published information addressing the status of their functions. Most literature to date addresses the factors necessary to initiate an accuracy control program.

The referenced articles on accuracy control implementation in U.S. shipyards conclude that for an accuracy control program to succeed, the shipyard must have product-oriented construction and process lanes (l). There must be a strong commitment from upper management, and the willingness to invest enough time to build the necessary data base for establishing process capabilities and monitoring improvement (2) (3).

U.S. Shipbuilding is not the first to implement statistical accuracy control in a manufacturing organization. A literature search of progress made in foreign shipyards and in other U.S. manufacturing industries brought to light some successful approaches to implementing accuracy control.

Implementation in European Shipyards. The international economic climate for commercial shipbuilding in European yards is just as competitive as for U.S. yards. In some countries, the shipyards are owned by the state, and commercial work is more evenly divided. This has not prevented some of those shipyards from closing due to international competition.

In 1985, as part of a SNAME SP-5 Human Resource Innovation Panel project, a survey was made of the status of product-oriented workgroups in European yards (4). The purpose of the survey was to learn how European yards use the participation of small workgroups to improve their work processes. Some factors these yards found necessary for change to occur were:

1. Strong directive from top management, i.e., "It will be done".

2. Job protection for supervisors who cooperate (with possible changes in job title).

3. Supervisor training in workteam management.

4. Leadership training for supervision.

5. Opportunity for groups to receive feedback and evaluate performance.

6. Suggestion program with monetary awards relative to the value of suggestion.

Similar observations were made by the Norwegian consulting firm of Bedriftsradgiving which participated in a Norwegian Shipbuilding Research Project from 1976 to 1980. They noted that group activities must be tied to quantifiable objectives, and intended outcomes should be made clear. Also, strategies must be established to involve key players of an organization (5).

All shipyards participating in the Norwegian Shipbuilding Research Project agreed that the potential for productivity increases depended on their ability to interface with and motivate people who perform the work. Advances in automated equipment or administrative control systems did not significantly increase productivity (5).

Implementation in Japanese Shipyards. The shipyards of Ishikawajima-Harima Heavy Industries Co. (IHI) have sought to develop an organization that promotes continual improvement and high productivity through worker participation at the small workgroup level. Their plan considers union representation and common work practices. The effectiveness of their organization also relies on a foundation of product-oriented design, material preparation, and planning (6).

The formal kick-off for the IHI continual improvement campaign was in 1969. Known as the 3Z or 3 ZEROES campaign: zero accidents, zero defects, and zero waste, it started with IHI top management issuing a formal policy to all shipyard employees, identifying areas that needed improvement in the following year. Areas such as safety, morale, productivity, and accuracy control were addressed. To date, a policy has been issued each year, feeding back the results of an analysis of each shipyard's major sources of costs, rework, and inefficiencies. To achieve the goals set forth in the annual policy, these steps are taken:

1. Quantitative annual targets for improvement are established by middle managers for each work process. These targets may be concerned with productivity, accuracy, and/or safety improvements. Guidelines for achieving the targets are also developed. Established work rates are an important

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                    ┌──────────────────┐
                    │ General Manager  │
                    │ IHI Shipbuilding │
                    └──────────────────┘
                             │
   Develop  Annual  ┌──────────────────┐
      Goals.        │   Manager of     │
                    │    Shipyard      │
                    └──────────────────┘
                             │
                    ┌──────────────────┐     Develops A/C
                    │   Manager of     │       targets
                    │  Hull Department │
                    └──────────────────┘   ┌──────────────────┐
                             │             │    Central       │
                    ┌──────────────────┐   │ Accuracy Control │
                    │ Section Manager  │───│     Group        │
                    │ Fab., Assy., Erect.  └──────────────────┘
                    └──────────────────┘
   Develop   ┌──────────────────┐          ┌──────────────────┐
 Implementation │ Staff Engineer │─────────│    Accuracy      │
 Plan and Quantitative └────────┘          │ Control Engineer │
    Targets                                └──────────────────┘
                    ┌──────────────────┐
                    │     Foreman      │
                    └──────────────────┘
              ┌──────────┼──────────┐
          ┌────────┐ ┌────────┐ ┌────────┐
          │ Assist.│ │ Assist.│ │ Assist.│
          │ Foreman│ │ Foreman│ │ Foreman│
          └────────┘ └────────┘ └────────┘
 Responsible
     for
 Implementation        3 to 10 workers
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Fig. 1 IHI Organization for Improvement
(Small Work Teams)

management tool for analyzing relative improvements made in process efficiency. Likewise, knowledge of current accuracy capabilities is required to monitor relative improvement.

2. Each workstation or workteam is tasked to achieve the annual targets established for them. Everyone in the company belongs to such a workteam and receives training in problem solving methods. This includes understanding statistical charts, graphs and data collection methods.

3. Each workteam meets at the beginning of each shift, and also twice a month for one hour to discuss their plans and progress in reaching their target. Interim targets are evaluated and revised quarterly by the workteam members.

4. An employee suggestion system is considered an important factor in providing the workforce a method to have their ideas for improvement implemented. A portion of the manager's annual evaluation is based on the number of good suggestions that are implemented in his area. Thousands of suggestions are accepted and implemented each year (approximately one per employee per month).

Small monetary awards are given based on the quality of the suggestion.

5. Large meetings for giving recognition to workteams are held quarterly and annually. Specific workteams are publicly recognized for submitting large quantities or good quality suggestions and also for achieving annual targets ahead of schedule.

The cost of training, recognition meetings, and suggestion review each month is high, but considered well spent by IHI. IHI feels this Feedback and Suggestion Program is the key to higher productivity and morale. Because good morale is considered an important motivational factor for worker participation in continual improvement of processes, more than ninety-nine percent of all employee suggestions are implemented, usually within one month (7).

As in European yards, direction is from the top down and implementation is from the bottom up. Analysis of data gathered during the year on work rates and rework enables management to set attainable targets for improvement.

At the IHI yard in Kure, a centralized Accuracy Control Department sets targets statistically as guidelines for

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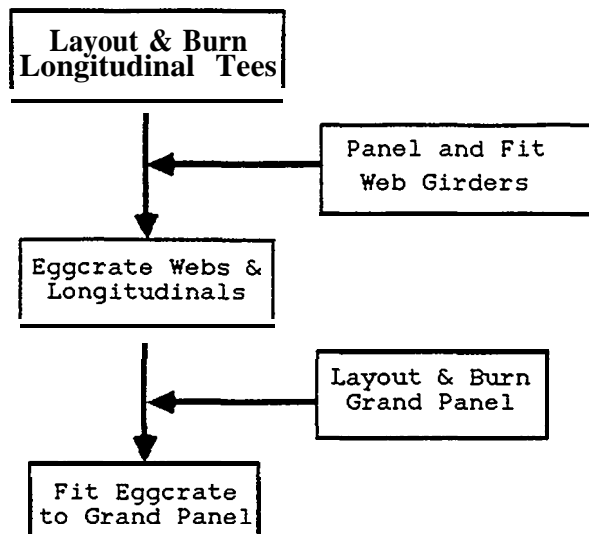
Fig. 2 Process Lane for Flat Midbody Blocks

Fig. 3 Typical Flat Block (Side Shell)

improving accuracy of vital dimensions. Recommendations for achievement are included with these targets which are revised every six months. All Hull Department Management must approve the accuracy control targets. The organization structure that has evolved over the past fifteen years to support this process offeedback and implementation is shown in Figure 1.

Implementation in Other U.S. Industries. The distinction between the statistical quality control programs used in other industries, and the dimensional accuracy control addressed in this paper is minor. Dimensional accuracy control in shipbuilding is one application of statistical quality control methods. In shipbuilding the accuracy of vital dimensions on interim products is what needs to be kept in statistical control. In a design company it may be the number or type of drawing errors which need to be monitored with statistical control charts. In a purchasing department a statistical control program might be introduced to identify problem suppliers.

Many companies in other industries with successful statistical quality control programs used consultants for guidance in starting and maintaining their programs. The resulting education of management in the use of statistical control methods was a key factor in the success of these companies.

Two of the most noted consultants in this group are Dr. W. Edwards Deming and Dr. Joseph M. Juran. In the 1950's they formed the basis of the Japanese quality programs. In the late 1970's, due to Japanese competition, U.S. industry sought the help of these men (8).

Status at Onset of Project

Status of Process Lanes at Onset. At the onset of this project there were two established process lanes functioning in the yard for the construction of tanker midbody blocks. One process lane was for flat blocks and the other was for curved blocks. The lanes were in place for sub-assembly and assembly. They stabilized the workforce at each workstation and optimized material flow for each block type. This contributed to the success of decentralizing Accuracy Control because workers had fewer checking procedures to learn and were more familiar with their work processes. Figure 2 illustrates the flat block process lane. Figure 3 shows a typical flat block.

Status of Accuracy Control at Onset. The Accuracy Control Department at National Steel and Shipbuilding Company was formed in October, 1984 with the purpose of analyzing work processes and making recommendations for improvement. The focus was to reduce production manhours by shipping more dimensionally accurate products to follow-on stages of construction. It was realized early on that to achieve this goal yardwide, the production workforce had to become actively involved.

The A/C Department was started with two full-time members. After ten months it was expanded to a total of seven including one person on third shift and two on second shift. Prior to the start of this study, progress had been made in training the hourly workforce to check

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vital dimensions, and workstations had been exposed to regular data collection over the previous ten months. This included some workstation members that had been taking their own daily data samples. This data was analyzed by the Accuracy Control (A/C) Department on a weekly basis.

Accuracy Control representatives periodically attended the short meetings held for each trade at the beginning of each shift. The A/C representatives answered questions, solicited feedback, and discussed the positive downstream effects of improved accuracy. Most importantly the analysis of data collected at that workstation was discussed.

Pre-planning activities by the A/C Department included the development of an Excess Material Plan to be used in the fabrication, assembly and erection of the midbody blocks of two 209,000 DWT oil tankers. This plan called for material to be added for normal (in-process) variations, such as predicted weld shrinkage. All other variations were designed to be adjusted with one inch of excess material located on every third hull block. These "adjusting butts" allowed for maintenance of contractual length, breadth, and depth tolerances of the ships. The plan for building two-thirds of the midbody section "neat" differs from hull construction approaches, where one inch of excess was allowed on each hull block. This past method for usage of excess resulted in the expenditure of many extra manhours for trimming and fitting of parts and plates at erection.

To reduce manhours at erection. each stage of construction had to build its parts, sub-assemblies, and assemblies within specified tolerances, and perform in-process checking. A booklet containing sub-assembly vital points and checking procedures was issued to foremen and hourly employees. Education meetings were held to explain the contents and use of this reference guide. The booklet addressed each process, such as webs, panels, and floors. Since the vital points were the same for each process, regardless of the size or shape, generic checksheets were developed. This eliminated the need for specific checksheets to be prepared ahead of time.

SECTION IV

METHODOLOGY USED FOR DECENTRALIZATION

The methods used to decentralize accuracy control at NASSCO are similar to those already in use by other manufacturing industries. They have been modified as required to suit the fabrication and assembly processes used in a shipyard work environment.

In this study, the decentralization of statistical accuracy control responsibility had three phases of implementation:

Phase I.   Determine maximum tolerances acceptable for erecting neat blocks without rework. Analyze standard assembly procedures for flat blocks types and develop standard checking procedures and tolerances.

Phase II.   Introduce standard checking procedures and tolerances to the hourly workers at each stage of construction. Give the workteam feedback on analysis of data collected from their workstation, in the format of percentage out of tolerance charts.

Phase III. Introduce statistical control charts to the members of the workstation as a tool to refine the accuracy capability of their work process. Give training in how to plot daily random samples of data.

Phase I

An analysis of each process in the construction of flat blocks was the first phase. The data collection and analysis in this initial study was undertaken by the Accuracy Control Department. The steps used were:

1. Identify the recurring problems arriving at erection from earlier stages of construction.

2. Use problem solving methods to determine likely causes of rework.

3. Collect data on likely causes of rework.

4. Analyze data and recommend changes to process.

5. Make Production Supervision responsible for implementing changes with technical support provided by A/C Department.

6. A/C Department monitors for improvement.

From this preliminary analysis, procedures were developed for two types of checking:

IN-PROCESS CHECKING: Done at each step in the process by the hourly worker as a self check. Data is not necessarily collected.

VITAL POINT/VITAL DIMENSION CHECKING: An overall check of a block or sub-assembly prior to welding. A designated person was made responsible for these checks, and for data collection.

Phase II

The next phase involved teaching the hourly workforce to correctly follow the checking procedures and continually try to improve the accuracy of their work processes. This was achieved as follows:

1. Introduce concept of workteam and accuracy control to area supervision.

2. Instruct workteam on tolerances and in-process checking procedures.

3. Data collection by A/C Department and presentation of data analysis to workteam.

4. Provide training in the understanding of statistical control charts to supervision and subsequently to workforce.

5. Post statistical control charts at the workstation, with A/C Department plotting data.

Initial upper and lower statistical control limits were calculated from at least ten consecutive daily subgroups of data previously collected (five samples per subgroup). The initial target for the workteam was to stay in statistical control (within upper and lower control limits).

Phase III

Once the process was in statistical control. the workteam could concentrate on eliminating common cause types of error from their work process. This is the continual refinement stage that will reduce the percent defective and at the same time bring the control limits of plus or minus three standard deviations within the specified tolerance limits.

1. Workteam meets to discuss ways to improve process and bring control limits within specified tolerance limits. Foreman and staff engineers participate and help facilitate worker recommendations for removing outside sources of error.

2. Provide training to supervision and workforce in how to actually plot the data.

3. Designate (ask for volunteer) member of the workteam to take daily random sample and plot data point. A/C Department also continues to take daily random sample to verify that the workstation remains in control.

4. Workteam meets regularly with A/C representatives, supervisors, and staff engineers to identify common causes of error from processes, including feeding back information on errors to early stages of construction.

5. Provide frequent recognition of accomplishments, both to workers and supervision.

SECTION V

IMPLEMENTATION AT THE MANAGEMENT LEVEL

Gaining Commitment of Upper Management

The top management of National Steel and Shipbuilding remained committed to the implementation of accuracy control yardwide. This was evidenced by their acceptance of the design to build without excess material on each hull block. This plan requires good accuracy throughout the midbody construction process since gaps resulting from short material would result in an expensive problem at erection.

Company management showed an equal commitment to the development of its human resources. All supervision was encouraged to use the first portion of each shift to hold meetings with the hourly employees reporting to them in order to advise them of work to be done, schedules to be followed, and any other information deemed useful to the employees. This meeting also provided time for the hourly employee to present ideas for improvement.

Training was also provided in statistical accuracy control methods to supervisors and hourly employees participating in this project.

Agreement on Supportive Organizational Structure

Production Department Organization. The organization under which this decentralizing effort developed was as follows: a Production Department managed by the Sr. Vice President for Operations with the Director

of Hull Outfitting and the Director of Hull Structure reporting to him. For this project, accuracy control implementation took place only in the Hull Structure Department. The Director of Hull Structure is responsible for the Fabrication Shop, Assembly, and Erection. To facilitate these operations, there is an Assistant Superintendent for each area. There is also a Chief Welding Engineer in charge of Welding, Burning, and Chipping. He provides technical support and supplies personnel to both the Hull and Outfitting Departments.

Within each hull group (i.e., Fabrication, Assembly, Erection) are two staff engineers and a traditional General Foreman, Foreman, Leadman hierarchy.

Accuracy Control Organization. The Accuracy Control Department was formed approximately one year before the onset of this study as a Staff Department supporting the Director of Hull Structure. The Supervisor of Accuracy Control reported to the Director of Hull Structure. The Accuracy Control Department had two degreed Engineers (Accuracy Control Analysts) and four Technicians with hull design experience. These numbers remained stable throughout the majority of the study.

When the Technicians joined the Department, they were trained to make vital point checks at subassembly and assembly workstations. Later, their responsibilities expanded to include teaching the foremen and hourly employees checking procedures. It was soon discovered that even though errors were being identified early, the necessary corrections were not being made before the product was shipped. Also, it was not possible for the four Technicians to thoroughly check all the blocks and sub-assemblies being built and conduct the necessary training. It became apparent that more manpower was required.

Instead of hiring more technicians, the plan to decentralize the responsibility of collecting data and plotting the data on histograms was accelerated. One highly skilled and motivated shipfitter was chosen from each of the main assembly workstations to be trained as Accuracy Control Field Checkers. These field representatives still reported to their foremen, but their first responsibility was to perform vital point checks of the assemblies and to make any necessary corrections. The rest of their time was spent shipfitting. Figure 4 shows this organization for the Hull Structure Department.

Proposed Accuracy Control Organization. It was anticipated that increased responsibility would be placed with the hourly Field Checker for supporting the accuracy control needs of his/her workstation. The increased responsibilities of the Field Checkers would include plotting the data they collect on histograms, percent defective charts, and statistical control charts. They would also be given the important task of feeding back
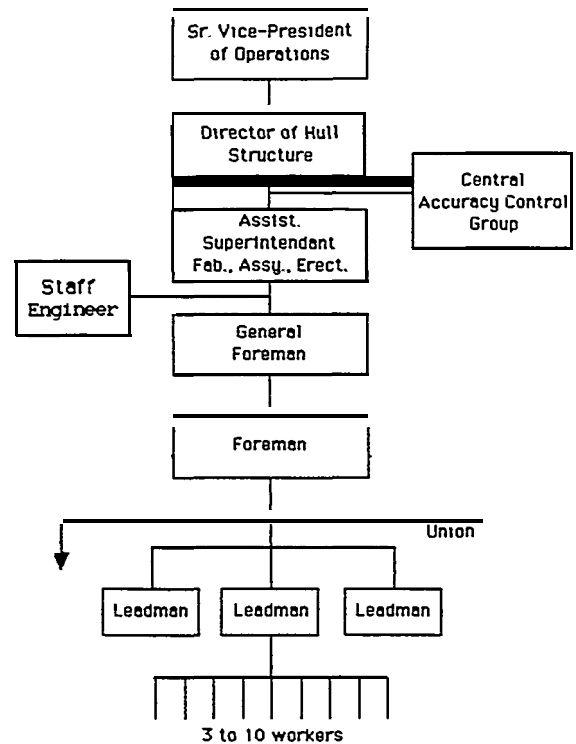
Fig. 4   Initial Organization of Hull Structure Dept.

the results of their data collection to the other members of their workstation during meetings at the start of the shift. In-process checking would remain the responsibility of each hourly employee.

In this proposed evolution, a small central Accuracy Control Department would still exist, but its function will evolve from one of data collection to one of coordination, training, preplanning for future contracts, and analysis of new processes. This group will also develop the vital points for each block type and standard formats for check sheets. Data from the accuracy control Field Checkers will be compiled and published by the Central Accuracy Control Group. Periodic progress reports will also come from this central group. Figure 5 illustrates the proposed supporting organization for decentralized accuracy control.

Education of Management and Direct Supervision.

The education of management and direct supervision is one of the most important aspects of any new program. An accuracy control program is no exception.

Just prior to the start of this study, the Sr. Vice President for Operations and the Director of Hull met with all Hull Department Supervision on all three shifis. The Supervisors were asked for their commitment for imple-

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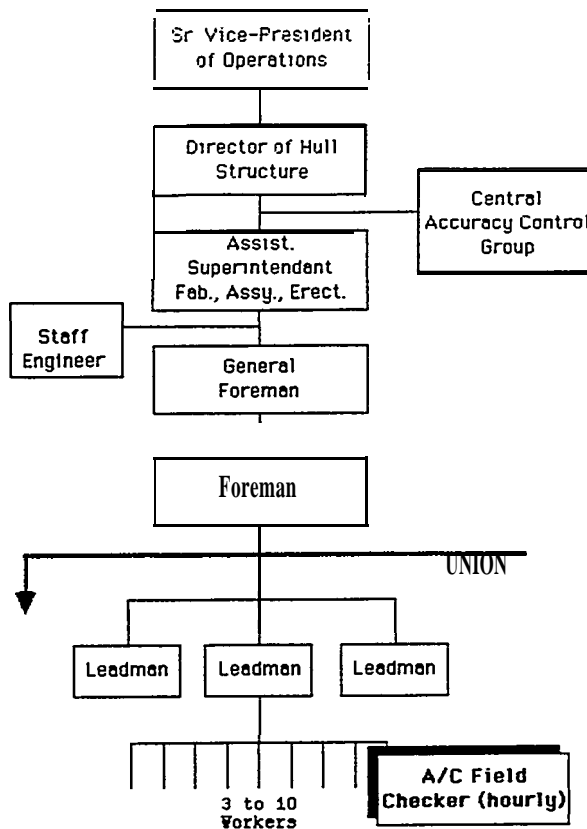
Fig. 5 Present Organization of Hull Structure Department

menting in-process checking procedures and hourly worker education about vital construction dimensions.

Soon after these meetings the previously discussed Vital Points Booklet was issued by the Accuracy Control Department. A series of meetings was held to distribute the booklets and to educate the supervisors about the vi-

tal points to check. Once the supervisors were trained, they were tasked with educating the workers.

In three months, training sessions on control charts were started. Supervisors and hourly workers were trained in the theory and maintenance of XBAR and R Charts. The hourly workers and foremen at the Fabrication workstation learned together how to plot data points on the control chart. At least one foreman seemed embarrassed that he did not understand, and expressed his discouragement in front of the hourly workers. To eliminate this problem in later training sessions, the foremen were trained prior to the hourly workers.

Several times, it was necessary to re-explain to participants on all three shifts that as long as each shift stayed within their respective control limits, it did not matter how their data compared with the other shifts. These explanations helped, but they indicated that the understanding of control charts and control limits was not solid, and was easily forgotten without a periodic re-explanation.

Along with this classroom training, supervision of Fabrication and Assembly viewed educational video tapes from the Audio Visual Material Available for Shipyard Training (AVMAST) Library at the University of Michigan (9) (10).

Just prior to the start of erection on the second tanker, a kickoff meeting was held with supervision assigned to this task. Training included building with the "neat system", fitting strategies to optimize accuracy, excess material plans and other accuracy control information.

The education of management and supervision is an important process that must precede the training of hourly workers. This is illustrated by the success of companies in other industries who have already implemented statistical quality control programs and followed this rule.

SECTION VI

IMPLEMENTATION AT HOURLY EMPLOYEE LEVEL

Introduction of Motivational Factors

Previously referenced literature recommended that a workable motivation factor would increase the interest of the hourly workforce for improving the accuracy of their products. It is a false assumption to believe that motivational factors alone will eliminate worker errors.

Through training sessions and discussions it was determined which training methods increased or decreased worker interest in improving the dimensional accuracy of their work process. A summary of these positive and negative factors is presented in Table 1.

Table 1. Positive and Negative Motivational Factors

Positive	Negative
Pride in workmanship.	Saving the Company money.
Quality work won't be reworked later.	Saving manhours.
Checking is part of the job.	Shorten contract duration.
Work smarter not harder.	Accuracy is Japanese technology.
Accuracy at earlier workstations improves working conditions.	
Recognition of accomplishments.	

An important motivational factor for inspiring improved performance was frequent recognition of good work. Several articles and photographs have appeared in the company newspaper recognizing worker participation and accuracy accomplishments. The Sr. Vice President for Operations also made a personal appearance on all three shifts at the Fabrication workstation to recognize their dramatic improvement in accuracy. A certificate was presented to each shifts' workteam recognizing both workers and foremen.

In implementing accuracy control at the workforce level it was very important to gain the commitment and participation of the foremen. They responded positively to public recognition of good performance by their workstations. Whenever pictures were taken for the company newspaper it was made certain that the foremen were included.

Another way foremen and their supervisors were recognized was through the weekly report issued by the Accuracy Control Department. This report was an important tool that commented on progress at each stage of construction, and presented results of data collection. Whenever possible positive recognition of improvements was made.

One difference between this approach and others is that monetary awards were not introduced to recognize worker suggestions for improving the process.

Establishment of Workteams

A NASSCO workteam is defined as a group of people of one or more trade skills, working together with its supervision to improve its work process. The first workteams of this project were established in the steel Fabrication Shop. The marking and cutting of longitudinal beams to an accurate length was a process selected for several reasons:

1. Data gathering by A/C had been going on for ten months.

2. The process was simple and straightforward.

3. The accurate length of longitudinal was a vital dimension in erecting neat hull blocks.

The first step in establishing the fabrication workteam was to gain the support and understanding of the Assistant Superintendent and General Foremen. The following was requested of them at the onset:

1. Allow for training meetings of hourly workers up to one half hour every week.

2. Encourage self-checking and the following of checking procedures.

3. Work to eliminate causes of error outside the workers control.

4. As much as possible, do not move personnel around, instead, keep them working at one workstation.

The last item was the most difficult on which to reach agreement because management felt there was a strong benefit in keeping burners skilled by working in different areas. It eventually was agreed that when a new worker was brought in from a different workstation he/she would be trained right away in the specific checking procedures and tolerances. Most of the time the same people worked at the workstation, although as the workload shifted, they would be transferred as necessary.

The burning and layout trades were the two groups at the Fabrication workstation. Each group met separately with its foreman for a meeting at the beginning of each shift. This made the establishment of a multi-skilled workteam at morning meetings difficult since other burners and layout people from the rest of the Fabrication Shop also attended the meetings.

It was decided not to isolate the workteam into separate morning meetings because there was only one layout foreman and one burner foreman. The solution was to continue the morning meetings as is, but gather both groups together (about 20 people per shift) when making a presentation about accuracy control. This way, all hourly burners and layout people were up to speed on A/C implementation. This seemed to work well, and added the benefit of having people already trained if some movement of personnel occurred.

Selection of Accuracy Control Targets

It is generally accepted that arbitrary numerical targets set by management are not effective motivators for

improvement and can be very demoralizing to a workteam. Often the targets are unattainable because a large percentage of defects are caused by sources outside the control of the hourly worker (11).

Before setting targets it is first necessary to identify whether the causes of the errors are operator-controllable or management-controllable. Some examples of these two types of errors are:

Management-Controllable (Common Causes):

- Poorly maintained equipment
- Inadequate facilities, poor lighting, unlevel work area
- Ambiguous work instructions

Operator-Controllable (Assignable Causes):

- Inadvertent or accidental errors, poor concentration
- Errors due to lack of technique and training
- Willful errors

The main use of a statistical control chart (XBAR and Range) is to identify the presence of operator-controllable or assignable causes of error. If a process is operating without any assignable causes of variation and only normal random variation is present, the process is said to be in statistical control or "in control". On an XBAR and Range Chart, if the average of the measurements of a sample is within the upper and lower control limits it can be assumed that the process is in control. Figure 6 shows an example of an XBAR and Range Chart used at the Fabrication workstation.

The upper and lower control limits represent plus and minus three standard deviations around a mean value for the process. These control limits will predict approximately ninety-nine percent of the averaged sample of data points as long as the process remains the same and no assignable causes of error are introduced. Control limits should be calculated after at least 50 individual measurements (e.g. 10 samples of 5 each) have been collected with no assignable causes of error appearing in the data (11).

An important point is that even though the process may be in statistical control, with no assignable causes of error, the percentage defective or percentage out of tolerance may be unacceptable to management. If this is the case, the process needs to be altered and sources of management-controllable (common cause) errors have to be sought out and eliminated. It is also possible that all assignable causes of variation were not removed from the process when the control limits were calculated.

Fig. 6 Example of Control Chart used at Workstation

With this basic overview of the use of statistical control charts it can be seen why placing all the responsibility of improving the percentage out of tolerance on the hourly employee will not produce the desired results.

In this study the foremen and hourly workers were asked to stay within the control limits day-to-day, and work together with management to identify sources of error outside the workers control. The target for each shift at the workstation was to refine their work process until the upper and lower control limits fell within the specified tolerance limits such as $\pm \frac{1}{16}$ inch. Once this target was achieved, the small percent that fell out of tolerance would be considered acceptable, although refinement of the process to eliminate more sources of error would continue.

Education of Hourly Employees

Training the hourly employees in checking procedures and in the use of statistical charts was successfully accomplished. Training in checking procedures usually took place at the short meeting at the start of the shift. Written checking procedures were provided along with a graph of recent data describing the workstation's performance to the design dimensions. Many times the hourly employee did not know the standard tolerances for his/her work process. In general, they took the data results very seriously and improvements in accuracy were promptly seen in most cases. Follow-up at the Worksite during the day assured that the information presented at the beginning of the shift was fully understood.

For the Fabrication workteam, this introduction to checking procedures and review of tolerances occurred four months before the start of this study. During this period, data collected by A/C personnel was presented in the format of a percent out of tolerance chart. These graphs were made for each shift at the Fabrication workstation and discussed at the daily meetings.

Soon after the hourly workers had been trained in the checking methods, the percentage-out-of-tolerance longitudinals dropped sharply and then leveled off, but was still at an unacceptably high level. A statistical control chart analysis confirmed that two of the shifts were in control. The control limits were outside the specified tolerance limits though, which explained the unacceptable percentage out of tolerance. The next step was to encourage input from the hourly workers to identify errors that they did not control. At this time training was provided to the hourly workers and foremen in maintaining control charts on a daily basis. This training by the Accuracy Control Department took place in a training room away from the worksite. Although everyone received hands on experience in the classroom, at first only one person was made responsible for collecting and plotting the data at the worksite.

SECTION VII

QUALITATIVE RESULTS

Attitudes of Management

Top Management. Top management remained committed to training the workforce in vital point and in-process checking throughout the project. Their commitment became apparent when, even as schedule pressures peaked, it was agreed to have one shipfitter at each Assembly work area trained in accuracy control methods. He was responsible for making vital point checks, collecting data and making corrections as necessary.

Upper management was also an important part of the recognition program for special achievements in accuracy improvement. Their participation in recognizing good performance confirmed to the employees the company's commitment to accuracy.

Upper management expressed a growing interest in the improved communication the Accuracy Control program generated. They were especially interested in the weekly reports updating progress, which included summaries of analyzed data.

Middle Management and Line Supervision. Initial meetings were held with Assistant Superintendents, General Foremen, and Foremen to discuss the basic goals of the decentralizing plan. There was no resistance to this plan but, as schedule pressures increased, these managers were more reluctant to have a skilled shipfitter taken away from his tools to collect data, or to take care of rework. This concern dissipated as the designated shipfitter soon became expert in not only the correct checking procedures, but also in assembly procedures. This made the foremen's job easier because the shipfitter could help instruct the other hourly employees.

Hourly Workforce/Union Response

During implementation, the following opinions were common among the hourly workforce:

1. Most workers were interested in knowing if their workstation was improving.

2. They felt increased pressure from foremen to be accurate.

3. Data collection by A/C personnel made them nervous.

4. For a new person to the workteam, there was anxiety in having to follow a precise checking procedure, and to perform within a tolerance.

Initially Union Representatives expressed concern about requiring the workers to put their initials on their work. The Union felt that this data might be used to reprimand or punish workers with high error rates. It was explained to the union shop stewards that the use of data to single out workers for punishment would not occur, since it would discourage teamwork at the workstation between workers and supervision.

It is interesting to note that statistical control chart data can actually defend the hourly worker if his/her workmanship is in statistical control, and yet the percentage out of tolerance is unacceptably high to management. This is true since, once a process is in control, errors still occurring are the result of management-controllable (common) causes.

Unexpected Problems or Evolutions

In teaching the employees how to plot their own data on control charts, the theory was taught first, and the mechanics of plotting the data points on the chart second. The theory of normal distribution and upper and lower control limits was not easily understood. This discouraged the participants and increased their apprehension toward learning how to plot the data on a control chart. Fortunately, they did learn the mechanics of how to plot the data, and at later meetings the theory was re-explained to this group. When teaching subsequent groups about control charts, less emphasis was put on teaching the meaning of upper and lower control limits, and more emphasis was put on how to plot XBAR and Range points.

SECTION VIII

QUANTITATIVE MEASURES AND RESULTS

Measures and Results

Rework is defined as unplanned work to correct inaccuracies, errors, or distortion. These errors can be in fabrication, fitting, engineering, or lofting. The collection of rework data is essential to an accuracy control program. Without this data and subsequent analysis, management cannot identify and correct problem areas.

In a series of ships, it is difficult to assign an improvement in productivity to any one cause. In addition to improved accuracy, savings could be attributed to an experience curve, components of which might be: improved shipwrighting methods, or design modifications. The question then arises, "How successful is the current accuracy control effort?".

At IHI Shipbuilding in Japan, rework is carefully documented, with each process assigned a rework rate. Through collection of data on rework, an estimate of rework costs can be calculated and compared for each ship, hull block, or year. Relative improvements made at Erection are measured by comparing percentages of rework in terms of burning or welding footage. Comparison of rework footage (and not a comparison of overall

manhours), is the best measure of success for dimensional accuracy control at earlier stages of construction. This method of comparing rework footage was the one adopted by National Steel and Shipbuilding Company. Examples of the formulas used are shown below.

(1) % REWORK (BURNING) =

$$\frac{\text{UNPLANNED BURNING (FEET)}}{\text{TOTAL FEET OF NEAT PLATE EDGE}}$$

(2) % REWORK (WELDING) =

$$\frac{\text{UNPLANNED WELDING (FEET)}}{\text{TOTAL FEET OF PLATE EDGE}}$$

When rework data is broken down by block type, equations (1) and (2) can indicate if further analysis of a process is necessary. Figure 7 shows an example of percentage rework data. Each data point represents the percentage of burning rework for a group of six successive longitudinal bulkhead blocks.
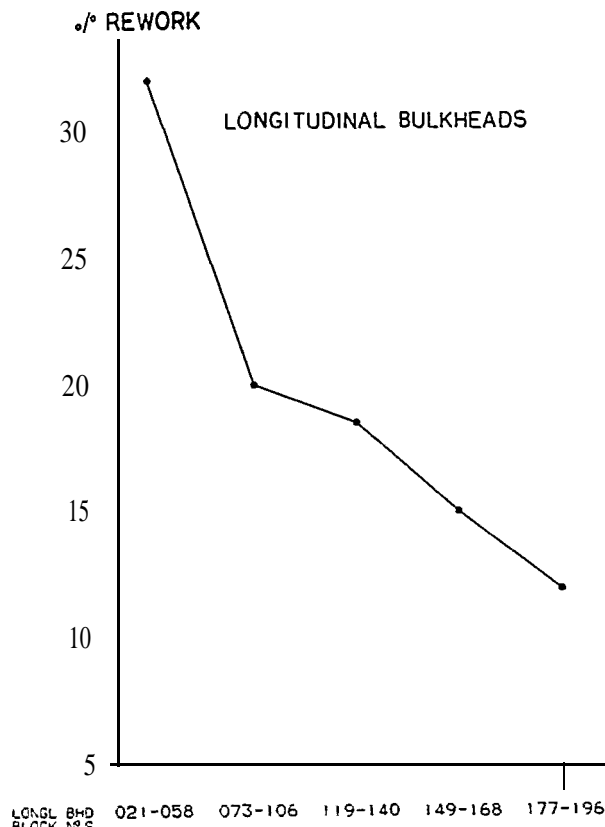
/° REWORK

LONGITUDINAL BULKHEADS

LONGL BHD 021-058 073-106 119-140 149-168 177-196
BLOCK N°S

Fig. 7 Rework at Erection
(Burning)

% out of
tolerance

Required tolerance
and checking procedures
explained to hourly
employees

Assignable causes of
error identified and
removed

Process in control
Workteam refines process
Common cause errors
removed.

month 1   month 2   month 3   month 4

Fig. 8   3 Week Averages of
Longitudinal Accuracy
(Length)

To gauge relative improvement at earlier stages of construction, percent out of tolerance charts were kept for each vital point.

At the Fabrication workstation a percentage out of tolerance chart documented the accuracy improvements. A distinct decrease in percentage out of tolerance occurred after each phase of the decentralizing methodology. Figure 8 shows the running three week averages of all the data collected at the Fabrication workstation during the first four consecutive months of implementation. All the data shown on this chart was collected by Accuracy Control personnel. This data can be used to determine the savings due to reduction of rework of longitudinal beams.

Methods of Data Collection

The rework data for this study was collected from all the stages of construction.

To reduce the variation in measuring caused by the use of different tape measures, the company supplied each layout person at the Fabrication workstation with the same brand tape measure. Similarly, tape measures of the same brand were provided for the Fabrication area burners to check their work and were also provided to each area in Assembly and Erection. These tape meas-
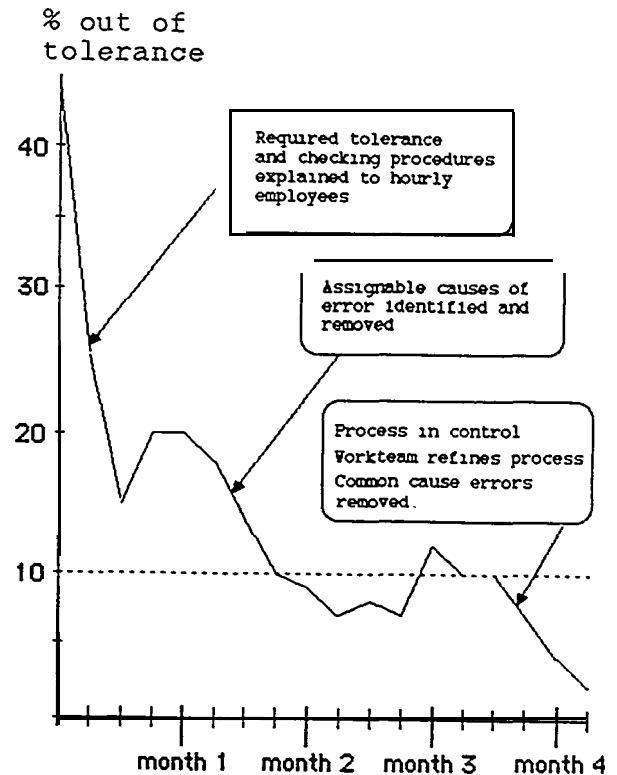
ures were regularly checked for accuracy against a new tape of the same brand.

Standard check sheets and written checking procedures were provided for vital point processes on all midbody blocks. All A/C personnel and Field Checkers were trained to use the same methods of checking. If a checking procedure was modified, each affected workstation would receive a revised procedure.

Check sheets were filled in by Accuracy Control Technicians or hourly Field Checkers. This checking took place in the Assembly area, before the block was released to Erection. The completed checksheets were forwarded to the Accuracy Control Department to be analyzed. Feedback of problems and trends were addressed through the appropriate production management channels, such as the weekly Accuracy Control Report, posted data and meetings with workers.

At Erection, data was collected and rework was recorded on a shell expansion drawing. This information was then transferred to data sheets for later analysis. The data collected consisted of unplanned trimming, welding, and plate inserting. The Foremen, Planners, and Staff Engineers at Erection participated in this data collection. Accuracy Control then collected the data

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sheets for analysis and feedback to earlier stages of construction. The Hull Planners were later given the responsibility of collecting the data, and became the equivalent of a Field Checker at Erection.

Factors Affecting Rework at Erection

Many factors affect the amount of rework at Erection at any given time. Some of those factors include schedule pressure, worker experience level and fitting procedure. During the tanker contract the manpower level in the yard increased significantly. Most of this increase came in the form of trainees. These trainees had to be in-structed on vital points and fitting procedures. During this time the trainee to journeyman ratio approached fifty percent.

The shipwrighting strategy of the Erection Department also affects rework. This strategy evolved throughout the tanker contract. Early in the contract, emphasis was placed on erecting each block individually and very accurately. Halfway through the first hull more emphasis was placed on erecting hull blocks as a group of neat blocks, correcting for any variation at an "excess" butt. This new strategy contributed to the decrease in rework at erection.

SECTION IX

SUMMARY AND CONCLUSIONS

This paper has described the three phase methodology used by National Steel and Shipbuilding Company to decentralize the Statistical Accuracy Control responsibility to the hourly workforce. The methods included in-process and vital point checking procedures, data collection, and plotting data samples on statistical control charts and histograms.

The measure of success of this program was the reduction of rework in the erection of hull blocks in the midbody of two 209,000 DWT tankers. A method for calculating reduction of rework at erection was presented. The lowering of percentage out of tolerance of interim processes at earlier stages of construction was also considered a successful indicator of improved accuracy. A chart of actual data collected after each phase of implementation illustrated significant improvement in dimensional accuracy.

1. Process lanes and standard assembly procedures are prerequisites to decentralizing the statistical accuracy control responsibility to the ship production workforce level.

2. Visible commitment from upper management throughout the implementation of this accuracy control program was important to the success of decentralizing.

3. It was important to gain the support and understanding of supervision early in the program.

4. A large decrease in "percentage defective" occurred immediately after the hourly workers were taught the correct checking procedures and the desired tolerances.

5. A second and third large decrease in "percentage defective" occurred after assignable and common causes of error were removed.

6. Positive feedback and recognition from upper management was important to the participating supervisors.

7. Quick response to hourly worker and foreman suggestions was helpful in building a team spirit for continual improvement.

8. Honest collection of data by hourly workers was not a problem as long as the workstation was being monitored by Accuracy Control personnel.

9. First shift at the Fabrication workstation collected and plotted their own data. The other two shifts had their data collected and plotted by A/C personnel. There was no significant difference in the accuracy of the three shifts.

10. The hourly workers and their union did not make any protest to the added job responsibilities of collecting and plotting data on an XBAR and Range Chart.

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SECTION X

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3. Stephen Krajcsik, "The Use of Statistical Methods In Dimensional Process Control," NSRP Report, Volume 1, September, 1985.

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8. Jeremy Main, "The Curmudgeon Who Talks Tough On Quality, " Fortune, June, 1984.

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ADDENDUM

At the time the original portion of this report was prepared, statistical control charts had been introduced only to Fabrication workstations. Results from the implementation made at the Assembly stage of construction were not then available.

This Addendum presents a summary of the results from implementation at Assembly. Quantitative measures of improvement in reduction of rework at Erection are also presented.

The schedule for implementing the three phase methodology for Fabrication and Assembly workstation is shown in Figure A-1. A brief description of each phase is also given.

SCHEDULE OF IMPLEMENTATION

3 PHASES OF IMPLEMENTATION

PHASE I   DETERMINE CHECKING PROCEDURES AND TOLERANCES

PHASE II   INTRODUCE CHECKING PROCEDURES AND TOLERANCES/ FEEDBACK RESULTS OF DATA COLLECTED

PHASE III INTRODUCE STATISTICAL CONTROL CHARTS AND PROVIDE TRAINING IN USE. TRANSFER DATA COLLECTION RESPONSIBILITY.
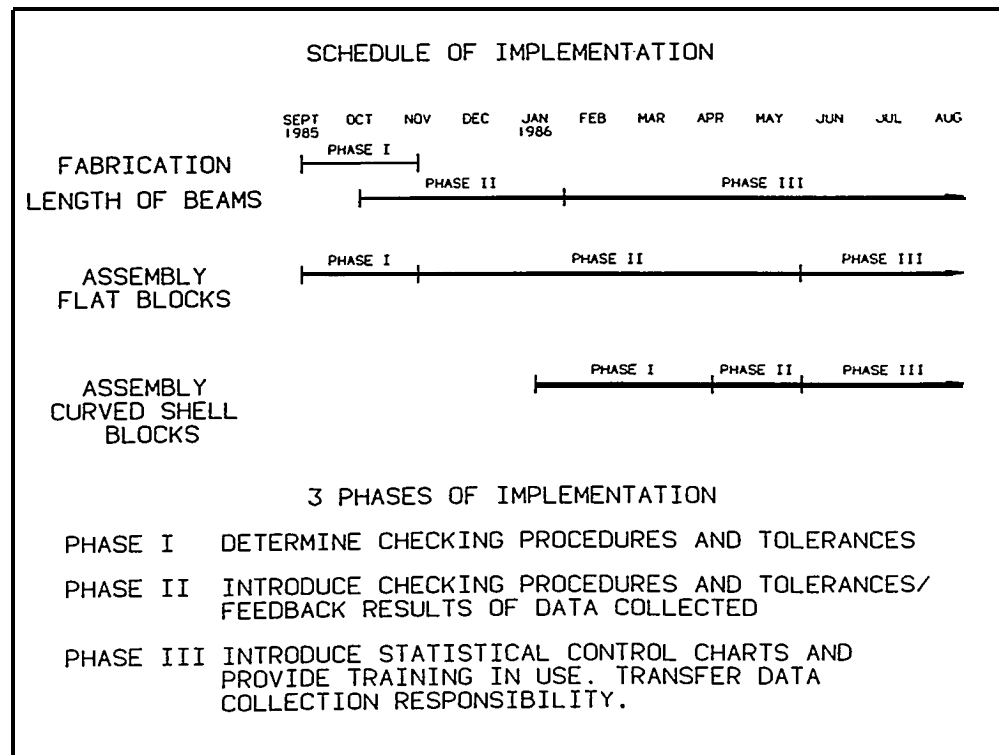
FIG. A-1

Figure A-1 shows that the Fabrication workforce received their training in control charts during February 1986. Four months later Assembly personnel from each workstation were trained in the use of control charts. Figure A-2 shows the workstation locations that received training in collecting and plotting data on X-bar and range control c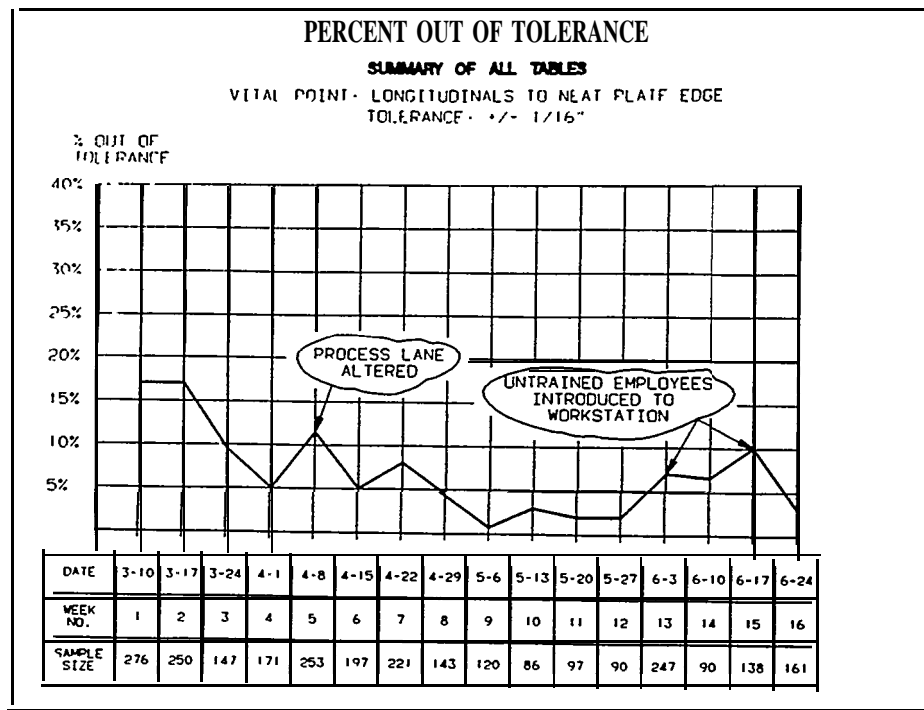harts. All the shipfitters and burners in Fabrication (approx. 50) received detailed training in the use and plotting of control charts. At Assembly, all of the shipfitters (approx. 150) received general training in the meaning of control charts. This training program included all Fabrication and Assembly employees who had a direct effect on accuracy.

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**WORKSTATIONS THAT RECEIVED
TRAINING AND RESPONSIBILITY
FOR STATISTICAL
QUALITY CONTROL CHARTS**

STAGE OF CONSTRUCTION	PARTICIPATING WORKSTATIONS	X BAR AND R CONTROL CHARTS FOR VITAL POINTS
FABRICATION	'ST SHIFT (AREA 9) 2ND SHIFT (AREA 9) 3RD SHIFT (AREA 9)	LENGTH OF LONGITUDINAL BEAMS
ASSEMBLY (FLAT BLOCKS)	**ALL SHIFTS:** TABLE 5 TABLE 8 TABLE I	LONGITUDINALS TO PLATE EDGE
ASSEMBLY (CURVED SHELL)	ALL SHIFTS: TABLE 2	CHORDS PIN HEIGHTS WEB FRAME DECLIVITY PLATE POSITION ON JIG LONGITUDINALS TO PLATE EDGE

FIG. A-2

A summary of the data collected over sixteen weeks is presented in Figure A-3 as a percentage out of tolerance chart for data collected at all workstations building flat blocks on the tankers. The process measured was the accuracy of fitting longitudinal beams to the neat edge of a grand panel. The week numbers (i.e. week no. 1, 2, etc.) apply to data that was collected systema analyzed weekly at Assembly. The results of this collection (initially by A/C personnel) were published i the Weekly Accuracy Control Report.

PERCENT OUT OF TOLERANCE

SUMMARY OF ALL TABLES

VITAL POINT· LONGITUDINALS TO NEAT PLATE EDGE
TOLERANCE· +/- 1/16"

FIG. A-3

The first upward spike at week 5 was the result of upperdeck blocks being built at workstations where shipfitters had not been trained in the assembly or checking procedures for upperdeck blocks. Both accuracy and productivity suffered when this change was made to an established process lane. Recognizing this, upperdeck construction was returned to its original workstation and workteam.

The second significant increase in errors at weeks 13 and 15 corresponded with the launch of the first tanker hull. At that time, many shipfitters, untrained in checking procedures were transferred from the building ways to the Assembly workstations. Most of these workers were assigned to second and third shifts. Unfortunately the Accuracy Control Department did not foresee this problem and the foremen did not assume responsibility for indoctrinating the new hourly and salaried personnel in assembly procedures, checking procedures, or tolerances. The result was an increase in the amount of rework as reflected in the data. Once the problem was identified, the new shipfitters were trained and the data quickly reflected the improvement.

The trends seen in Figure A-3 for the combined data from all Assembly (flat block) tables are also reflected in the data for each individual table as seen in Figures A-4, A-5, A-6, and A-7.

TRAINING ASSEMBLY PERSONNEL

Immediate feedback of accuracy performance was important. Covered bulletin boards were placed at each of the four Assembly workstations. Initially, data was posted daily and weekly by the Accuracy Control Department. Statistical control charts were posted at the Assembly workstations thirteen weeks after the start of Assembly data collection. Initially, these were also maintained by the Accuracy Control Department.
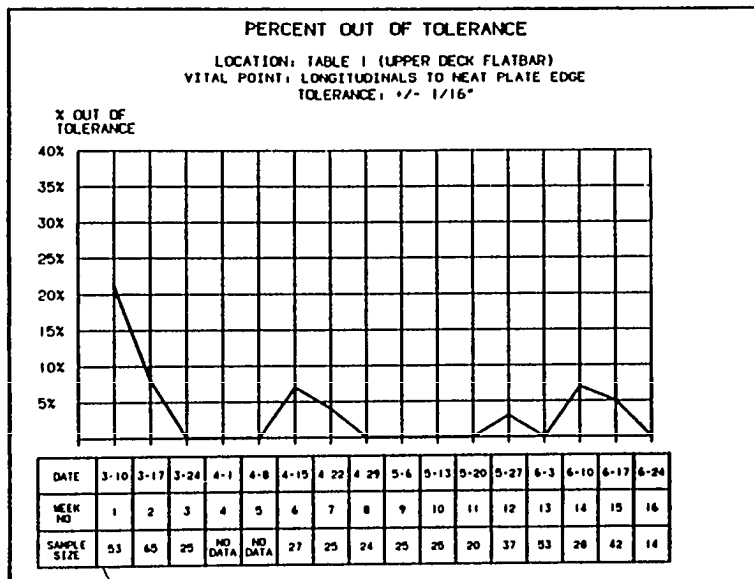
During week 14 of data collection, training was provided to the foremen and selected shipfitters in how to use control charts. Within two weeks of putting up the control charts, each selected shipfitter was plotting data samples on the X-bar and range control charts. The Accuracy Control Department provided technical support and continued the procedure of taking random samples to verify the results of the shipfitters.

While all Assembly shipfitters (approx. 150) were trained in assembly procedures, vital point checking and general control chart principles, the training sessions for Assembly personnel differed from training provided to
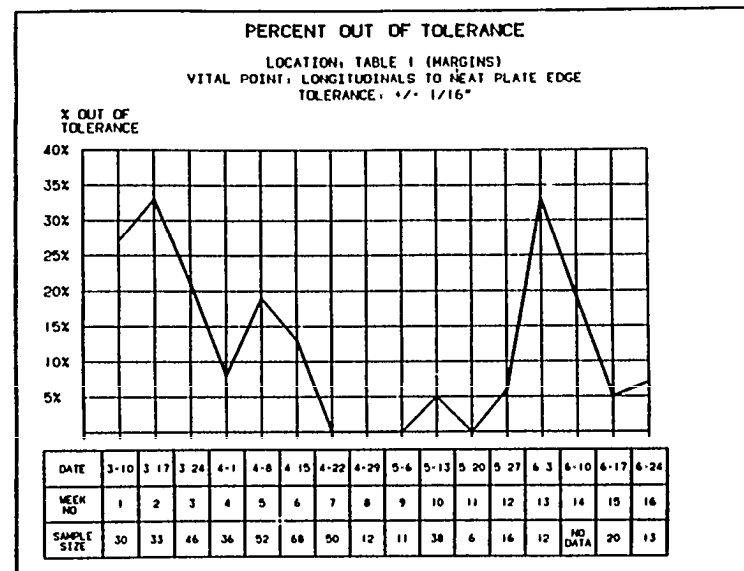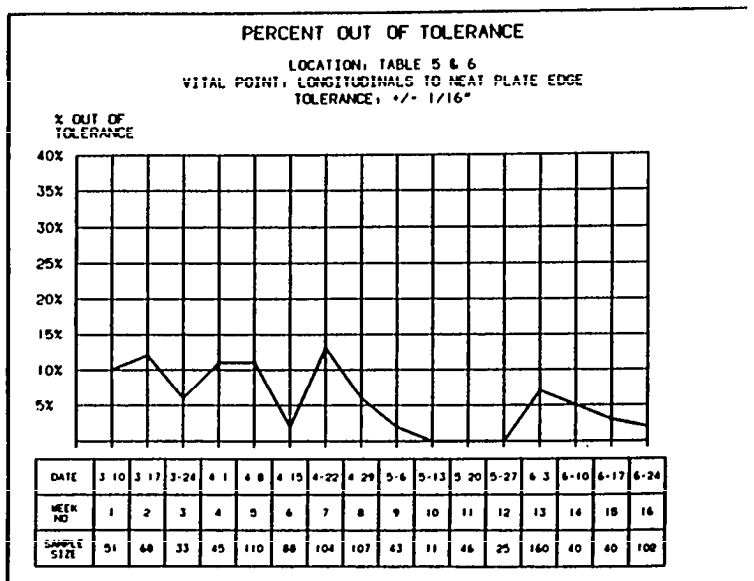
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PERCENT OUT OF TOLERANCE
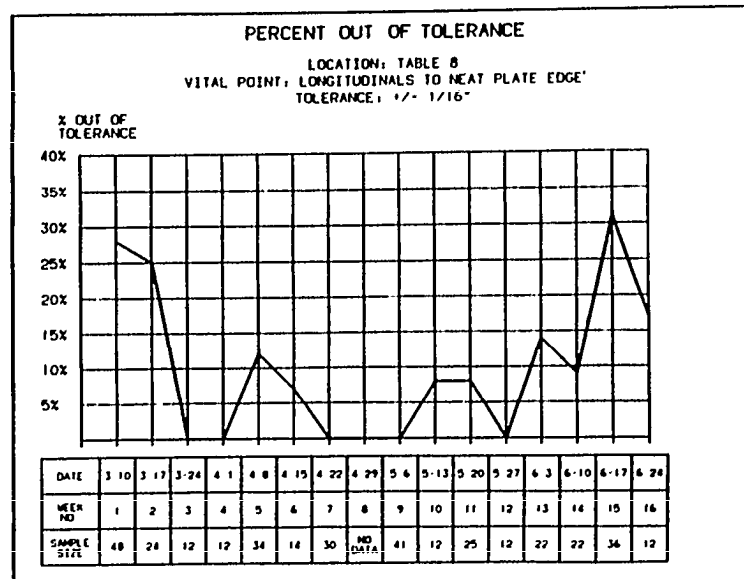
TOLERANCE: +/- 1/16"

TABLE I FLATBAR

PERCENT OUT OF TOLERANCE

LOCATION: TABLE I (UPPER DECK FLATBAR)
VITAL POINT: LONGITUDINALS TO NEAT PLATE EDGE
TOLERANCE: +/- 1/16"

DATE	3-10	3-17	3-24	4-1	4-8	4-15	4-22	4-29	5-6	5-13	5-20	5-27	6-3	6-10	6-17	6-24
WEEK NO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
SAMPLE SIZE	53	65	25	NO DATA	NO DATA	27	25	24	25	26	20	37	53	28	42	14

TABLE I MARGINS

PERCENT OUT OF TOLERANCE

LOCATION: TABLE I (MARGINS)
VITAL POINT: LONGITUDINALS TO NEAT PLATE EDGE
TOLERANCE: +/- 1/16"

DATE	3-10	3-17	3-24	4-1	4-8	4-15	4-22	4-29	5-6	5-13	5-20	5-27	6-3	6-10	6-17	6-24
WEEK NO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
SAMPLE SIZE	30	33	46	36	52	68	50	12	11	38	6	16	12	NO DATA	20	13

TABLE 5&6

PERCENT OUT OF TOLERANCE

LOCATION: TABLE 5 & 6
VITAL POINT: LONGITUDINALS TO NEAT PLATE EDGE
TOLERANCE: +/- 1/16"

DATE	3-10	3-17	3-24	4-1	4-8	4-15	4-22	4-29	5-6	5-13	5-20	5-27	6-3	6-10	6-17	6-24
WEEK NO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
SAMPLE SIZE	51	68	33	45	110	88	104	107	43	11	46	25	160	40	40	100

TABLE 8

PERCENT OUT OF TOLERANCE

LOCATION: TABLE 8
VITAL POINT: LONGITUDINALS TO NEAT PLATE EDGE
TOLERANCE: +/- 1/16"

DATE	3-10	3-17	3-24	4-1	4-8	4-15	4-22	4-29	5-6	5-13	5-20	5-27	6-3	6-10	6-17	6-24
WEEK NO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
SAMPLE SIZE	48	24	12	12	34	16	30	NO DATA	41	12	25	12	22	22	34	12

Fabrication personnel. Only one hourly employee (a shipfitter) and one foreman were trained from each Assembly workstation on the specific details of how to plot data on control charts. This detailed statistical control chart training consisted of two separate sessions. Session I[1] was for the Foremen, General Foremen and the Assistant Superintendent only. A video tape was shown and then a discussion was held focusing on the need for statistical accuracy control and control charts in modern shipbuilding[2]. An important point immediately brought up by these production supervisors was that for the company to achieve its goals for improvement, each department must be made responsible for maintaining statistical control of its own processes. This includes not only Production, but also the Mold Loft, Engineering, and Purchasing Departments.

Session II[1] of the training included both the salaried supervision mentioned above and a highly-skilled and motivated shipfitter from each Assembly workstation. A portion of another video tape was viewed that provided an excellent explanation of normal variation[3]. Understanding variation is an important prerequisite to understanding control charts.

Although in the earlier part of this paper it was stated that foremen and hourly workers would be trained separately to avoid any uncomfortable feelings on the part of the foreman, this was not done. Because the foreman and the shipfitter would become the core of the accuracy control effort at their workstation, it was felt that it would be beneficial to train the foreman and shipfitter together. Fortunately, this seemed to work well and no apparent problems resulted. It also prevented any confusion about assignment of responsibility.

As part of Session II, the accuracy control responsibilities of the foremen were reviewed as follows:

Responsibility of Assembly Superivision for Accuracy Control

1. Understand all the assembly and checking procedures for blocktypes built in your area. This includes fitting sequences and acceptable tolerances.

2. Train all personnel reporting to you in these procedures, especially employees transferred in from other areas.

3. Supervisors are responsible for the dimensional accuracy of products produced at their workstation and should monitor data collected and plotted on control charts.

4. Discuss the results of data collected at least once a week at the five minute meeting at the beginning of the shift. This includes being able to explain the purpose and basic elements of statistical control charts.

5. Continually develop the skill level of subordinates and give positive recognition of good work.

6. Periodically (no less than monthly) verify that the hourly employees have the correct and accurate tools.

7. Continually improve the system. This requires good cooperation and communication with supervisors, subordinates, and other trades.

Although only one shipfitter from each Assembly workstation was trained in how to plot the data, all shipfitters received an explanation of the purpose and meaning of the control charts. After the foreman received training, he was responsible for discussing the results of data collection at his workstation at least once a week with the shipfitters who worked for him. The information that was posted on the bulletin boards consisted Of:

1. Statistical control charts for each vital point process. (X-bar and range)

2. Percent out of tolerance on a weekly basis. (graph)

3. A summary of all Assembly workstations' performance. (Taken from weekly report, see Figure A-8 for an example.)
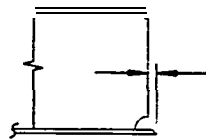
(1) See Appendix A, hereto.

(2) "The Deming Philosophy of Modern Management", produced by the University of Massachusetts-Amherst, available from the University of Michigan, Transportation Research Institute, AVMAST Library Index No. DE-18.

(3) "Activity Plans for Implementing Quality and Productivity", Part 2, produced by Myron Tribus Videotapes, available from the University of Michigan, Transportation Research Institute, AVMAST Library Index No. DE-19.

SUMMARY OF ACCURACY DATA COLLECTED AT ASSEMBLY WORKSTATIONS

THIS WEEK: 6-26-86 TO 7-3-86

VITAL POINT: OFFSET OF LONGITUDINAL BEAMS TO NEAT PLATE EDGE
TOLERANCE: +/- 1/16"

WORKSTATION LOCATION / A-2	NUMBER OF LONGITUDINALS CHECKED		TOTAL PERCENT OUT OF TOLERANCE		X-BAR (AVERAGE)		RANGE (VARIATION)	
	LAST WEEK	THIS WEEK	LAST WEEK	THIS WEEK	LAST WEEK	THIS WEEK	LAST WEEK	THIS WEEK
TABLE 5 & 6	40	102	5%	1.9%	+.006"	-.003"	3/16	5/16
TABLE 9	NO DATA	20	NO DATA	0%	NO DATA	-.003"	NO DATA	1/8
TABLE 8 & 4	36	12	31%	16.7%	+.042"	+.036"	3/8	3/8
TABLE 1 UPPER DECK FLATBAR	42	14	4.8%	0%	+.013"	-.004"	3/16	1/16
TABLE 1 MARGINS LB & SS	15	13	5%	7.7%	+.033"	-.010"	3/16	1/8

TOTAL VALUES FOR ALL ASSEMBLY WORKSTATIONS COMBINED:

LAST WEEK	133	11.3%	+.021"	3/8
THIS WEEK	161	3.1%	-.001"	1/2

$$\text{X-BAR} = \text{AVERAGE} = \frac{\text{TOTAL VARIATION FROM DESIGN}}{\text{TOTAL NUMBER OF LONGITUDINALS}} = \text{AVERAGE VARIATION IN INCHES}$$

RANGE = THE AMOUNT OF VARIATION. (THE DIFFERENCE BETWEEN THE HIGHEST AND LOWEST DATA VALUE)

FIG. A-8

QUANTITATIVE RESULTS AT ERECTION

Rework data at Erection was collected from the first and second EXXON tanker hulls, both for burning and welding rework footage in the parallel midbody blocks. Figure A-9 summarizes the percent of rework measured in the midbodys of the first and second hull. The significant decrease in rework between the first and the second hull has been attributed to improved dimensional accuracy at earlier stages of construction and improved erection methods.

PERCENT OF REWORK		
BLOCK TYPE	LENGTH TRIMMED / TOTAL EDGE LENGTH	
HULL #	438	439
BTM. SHELL CL	15.7%	6.4%
LONGL BHDS	22.1%	8.0%
TRANSV BHDS	25.3%	10.7%
UPPER DECK CL	16.4%	6.4%
ALL	18.8%	7.3%

HULL #	TOTAL UNPLANNED WELDING	TOTAL # INSERTS REQUIRED
438	258'	62
439	145'	9

Comparison of Rework at Erection
Hull 438 vs 439

FIG. A-9

FUTURE WORK

At this time NASSCO has achieved the preliminary organizational structure for decentralized statistical control at the ship production workforce level. Classroom training in the basics of control chart maintenance and theory has been provided to line supervision and hourly employees. Follow-up training has also been provided at each workstation to verify that the information delivered in the classroom was understood and will be applied correctly.

The future and continued success of this program is not guaranteed. Cementing the gains made to date relies on the Director of the Hull Department and the Assistant Superintendent at each stage of construction. They have the important responsibility of setting statistical targets for improvement. Each foreman must be accountable for the data collected each week and be able to report on new ideas implemented at his workstation to remove causes of error.

The next step at this time should be to develop a structure for setting accuracy control targets for each vital point process at each stage of construction. At IHI Shipbuilding in Kure, Japan, these targets are statistically established by the Central Accuracy Control Department and are signed off in agreement by each Section Manager (Assistant Superintendent). These targets are reviewed and updated every six months. Figure A-10 shows an example of the type of document produced by IHI that sets targets and establishes rework rates. A more detailed description of the IHI Shipbuilding system for continual improvement of all processes is contained in a report of the authors' observations during a visit to IHI's Kure Shipyard. (7)

A substantial database has been started for all vital point processes in the construction of both flat and curved block types contained in the tanker midbody section. This database along with variation merging equation methods, would be an important tool in setting meaningful accuracy control targets for each standardized process. The database could be used to statistically predict the rework to be encountered at the Erection stage of construction. It would be interesting to compare the theoretical prediction of rework. with the actual burning and welding rework footage that has been recorded in this study. The value of using variation merging equations to predict rework for different assembly sequences has already been discussed in earlier references. See footnotes (2) and (3) at Page 20 of this Addendum.

ITEMS TO BE REPORTED AS REWORK (REVIEWED EVERY 6 MONTHS)

					M	DM	DM	SM	ISM	SM	O.C
KEY ITEMS ON WHICH TO FOCUS OF ACCURACY CONTROL											
SECTION NUMBER	SECTION	CONTROL ITEM	CONTROL TARGET	ACTION ITEM	TOLERANCE		REWORK RATE				
F1	FABRICATION	FLAME PLANERS	SKIN PLATES	Monitor neat material	+/- 1/16"		30min/plate				
F2		BURNING N/C OR EPM	"L" within tol. ≥ 95% "B" within tol. ≥ 90%		+3/64" -1/8"		ditto				
F3		LONGITUDINAL LENGTH	INTERNAL MEMBERS: within tol.≥ 90%	Remove assignable causes of error.	+/- 5/64"		10 min/long.				
F4		BEVELS	mean value +/- 5/64" limit +/- 5/32"	Maintain statistical control.	+/- 2 deg.		ditto				
A1	ASSEMBLY	SHIFT DIMENSION OF LONG'S.	FLAT BLOCKS: in tol.≥90% CURVED within tol.≥ 95%	Inform Erection of erection joints data.	+/- 1/16" +/-3/64"		30 min/bevel				
A2		SHIFT DIMENSION OF TRANSVERSE	FLAT BLOCKS: in tol.≥90% CURVED within tol.≥ 95%	Maintain statistical control.	+/- 1/16" +/- 3/64"		ditto				
A3		FLATBAR SHIFT ON SUB-ASSY	within tolerance ≥94%		+ 0" -3/64"		10 min/flat bar				
A4		FACEPLATE SHIFT DIMENSION	within tolerance ≥93%		+/-3/64"		ditto				
A5		BREADTH OF GRAND PANEL	within tolerance ≥50% (neat cut on burn. mach.)		+ 5/32" - 0"		2 hr/panel				
A6		REWORK RATE OF CURVED BLOCK	Determined by past data (at seams)		+5/32" - 0"						
E1	ERECTION	BURNING & BACKSTRIP RATIO	Burning 23%, Backstrip 3%, total 26%	Reduce percent of burning & backstrip							

A/C TARGETS SET FOR IHI HULL DEPT. BY A/C DEPT.

FIG. A-10

APPENDIX A

TRAINING IN STATISTICAL CONTROL CHARTS FOR DIMENSIONAL ACCURACY CONTROL
NASSCO HULL DEPARTMENT: ASSEMBLY JUNE 1986

SESSION I.   "Traditional vs. Modern Views of Quality and Productivity in U.S. Shipbuilding"

1. Brief Introduction and Purpose: Continually improve system.

2. View 30 minute videotape (1) discussing the importance of continually improving the quality in U.S. shipbuilding.

<p align="center">Discussion #1</p>

-Does NASSCO have a corporate goal statement that addresses quality?

-Is quality one of your major concerns?

-Is it your responsibility to:
   Learn the system you work with?
   Understand the system?
   Change and improve the system?

<p align="center">Discussion #2</p>

-Do you believe that improved quality costs or pays?

-Do you agree that 80 to 85% of problems and costs of inefficiencies are in the system and not with the employee?

-Is it your responsibility to identify barriers to productivity and quality?

-Does the company use low bid purchasing methods?

-What is future role of line supervision at NASSCO?

Total time: 60 min.

(1)   "The Deming Philosophy of Modern Management,"" Produced by Univ. of Massachusetts-Amherst, AVMAST Library, Index No. DE- 18, Univ. of Michigan, Dept of Transportation.

SESSION II.   "Why Statistical Control Charts Are Necessary At NASSCO And How To Use Them"

1. Brief review of assumptions from Session I:

-The system is accountable for 80 to 85% of inefficiencies and poor quality.

-The system always has some variability from design.

-To control the variability in the system, it needs to be measured and monitored using statistics. (Control Charts)

2. View 15 minute videotape (2) discussing random variation and need for Control Charts. (35-minutes with discussion)

-Discuss videotape: randomness, difference between natural and assignable causes of error, fear in the workplace.

Random	Not random
Natural variation	Unnatural (System) variation
Common causes of error	Assignable causes of error
worker variation temperature humidity bad eyesight vibration from cranes	defective material tools need repair poorly maintained machines power surges in voltage bad lighting checking procedure not explained to all people

<p align="center">(10 minute break)</p>

(2) "Action Plans for Implementing Quality and Productivity," Part 2, Deming and Tribus Videotapes, AVMAST Library, University of Michigan, Department of Transportation, Index No. DE-19.

3. Purpose of control charts is to determine if a process is functioning randomly (natural causes of variation) and as expected. Define "statistically in control".

-Describe parts of a control chart.

-Explain purpose of plotting only 5 samples as an indicator.

-Explain function of control limits and in general how they are developed from past data.

-Train how to plot data on some example control charts.

-What role do tolerances play?

4. Explain how to interpret data and tell if process is out of control.

-Trends in data.

-Data points exceed control limits.

5. The responsibility of line supervision: improve accuracy of system using control charts:

   A. Have standard assembly and checking procedure.
   B. Collect data and calculate control limits.
   C. Plot XBAR (average) and Range values.
   D. Ask for worker input to identify and remove assignable (non-random) causes of error until data is in control.
   E. Ask for worker input to help identify and remove common (naturally random) causes of error.

-Keep a spiral notebook of suggestions or observations made at five minute meetings. Feedback results of suggestions to five minute meeting members promptly.

-Explain to hourly employees what NASSCO is doing to improve quality.

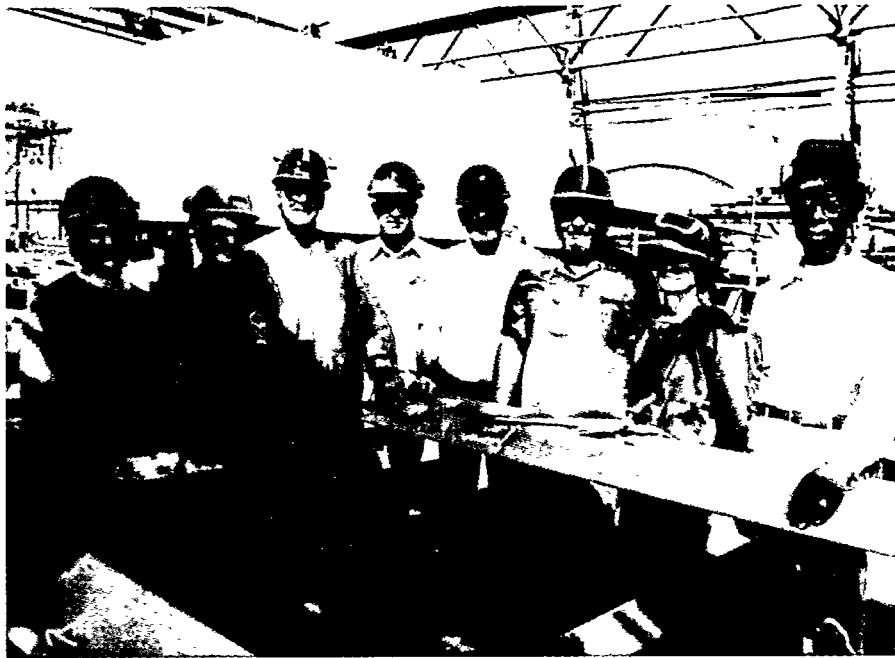-Discuss the results of data collection at the five minute meetings.

-Bring new workers in the area up to speed on procedures and the control charts.

-Use the staff engineers as a support group for implementing suggestions that remove sources of error.

(45 minutes)

(1 hour and 30 minutes total)

APPENDIX B

Plate Shop layout and burners who are participating in accuracy control of cut parts are (from left) Consuelo Vidal, Marie Hall, "Des'" Deslauriers, Jim Elkins, Carlos Pavne, J. "Bobbie" Gutierrez, Debbie Hatch, and "Max" Maxwell.

Plate Shop Layout and Burners Participate in New Accuracy Control Program

*by Tammy Upham, Accuracy Control Analyst, and
Dave Malmquist, Supervisor Accuracy Control*

Cut parts for sub-assemblies have been fitting up easier, thanks to the effort from the Plate Shop layout and burners.

By checking their work and recording the results, the accurate cutting of these parts has improved. Prior to implementing accuracy control methods, cut parts measured between $\pm 1/4''$. They are now falling within $\pm 1/16''$, which is within NASSCO standard tolerance.

The layout and burners are working in cooperation with the newly formed Accuracy Control Department. Dave Malmquist and Tammy Upham are the two members of the new group.

The goal of accuracy control is to have dimensionally accurate products (within tolerances) to ship to follow-on stages of construction. Accurate products improve working conditions by: (1) Reducing work at the erection stage, which is more difficult and not as safe. (2) Reducing rework caused by errors or inaccurate parts. (3) Improving fitting and welding conditions for follow-on workers.

The Exxon tanker contract will require increased accuracy awareness by everyone. Mid-body units are planned to be built neat, that is, without the usual 1" excess allowance. This plan, although reducing difficult fitting at erection, requires more attention to accuracy at earlier stages of construction. Keeping accuracy in mind in all areas, will mean a better, safer Exxon tanker program for everyone.

Accuracy Control: Fitting Foremen Asked for Commitment

by Dave Malmquist, Supervisor, Accuracy Control, and Tammy Upham, Accuracy Control Analyst

On August 27, Bob Hartman, Director of Hull Production, met with shipfitting foremen from all three shifts. The purpose of the meeting was to convey the importance of checking the accuracy of work performed.

Bob asked each foreman to commit to taking the message back to his employees that checking the work is part of the job; the job is not complete until the work has been dimensionally checked.

Active involvement by all shifts is needed to improve accuracy. Checking to assure that parts or assemblies are within NASSCO tolerances will reduce rework at later stages of construction where work is more difficult and less safe.

The Accuracy Control Department has been issuing documents to help foremen and journeymen determine vital dimensions for maintenance of accuracy. The Department has also issued accuracy check sheets to record these important dimensions. This recorded data is later analyzed to see if the building process can be improved.

Since the August meeting with the foremen, additional checks of vital dimensions are taking place. Data from these checks have led to recommendations for improving processes and obtaining greater accuracy in block construction.

Controlling accuracy and building accurate hull blocks is a key factor in remaining competitive and winning new construction contracts.

Second-shift layoutmen and burners have successfully maintained the accuracy of hand-cut parts. Kneeling, from left, are Homer Spell, Ernesto Amado, Steve Deslauriers, Ron Melencio, Tammy Upham (Accuracy Control Analyst); (standing) Rich Bailey, Gwen Ferguson, Martha Selman, Bob Stanley, Virginia Hernandez, Michael Riso, and Judith Mena. Also involved are Rafael Pedroza and Jerry Branson.

M

Significant Accuracy Improvements Accomplished by Burners, Layout

by Dave Malmquist,
Supervisor, Accuracy Control

On January 29 and 30, Don Spanninga, Senior Vice President, Operations, presented certificates of accomplishment and his personal thanks to the first-, second-, and third-shift burners, shop layout, and their foremen.

These men and women, who work at the "Longs Table" in the Plate Shop, are responsible for the layout and burning of longitudinal stiffeners for the Exxon tankers. Very close tolerances are required in the length of these longitudinals (± 1/16" in 40') because many units are being built neat — that is, without excess material.

A summary of this work station's achievements is as follows:

August 1985 — 44% out of tolerance
September 1985 — 16% out of tolerance
October 1985 — 10% out of tolerance
November 1985 — 8% out of tolerance
December 1985 — Burners develop their checking procedure
January 1986 — 4% out of tolerance
February 1986 — 0.4% out of tolerance
Such consistent efforts to improve the accuracy of their product has reduced rework at follow-on stages of construction.

In his remarks to the group, Don stated, "In order to secure new contracts, we must become more competi-

tive. To improve our competitive posture, we must assure the product being built is accurate before it goes on to the next work station. If every work station controls the accuracy of the work it performs, the end results will be less rework, lower costs, and safer work at follow-on stages of construction. In other words — we become more competitive. I want you to know that the Company and I appreciate your efforts!"

Don Spanninga, Senior vice President, Operations, (standing, far left) commands first-shift burners and layout for accuracy improvements. Kneeling, from left, are Marie Hall, José Muñoz, William Amos, Jr., Consuelo Vidal, Jesus Corona, Nathaniel "Max" Maxwell, Mike Krumweide; (standing) Jim Hammond, Jorge Castillon, Larry Harp, Keith Davis, Javier Chaires, Vince Dorio, Bobby Gutierrez, and Jesse Gallegos.

In presenting a certificate of accomplishment to **second-shift** burners and layout, Don Spanninga (standing, far left) offers congratulations for their significant accomplishment. Kneeling, from left, are Steve Deslauriers, Ron Melencio, José Aguirre, Armando Padilla, Mike Blouin, Eddie Minear, Ernesto Amado; (standing) Rich Bailey, Richard Ives, John Ryan, Judy Mena, Virginia Hernandez, Martha DeSelma, Rafael Pedroza, and Bob Stanley. Not pictured: Mike Rizo and Homer Spell.

"I want you to know that the Company and I appreciate your efforts," says Don Spanninga (standing, far left) in recognition of the efforts of **third-shift** burners and layout to improve accuracy. Kneeling, from left are Mike Salini, Mike Salis, Mizell Smith, Ron Sandoval, Salvador Jimenez, An Ngo; (standing) Arnold Rietz, Mike Little, Armando Ceballos, Gary Randolph, Nick Peñaloza, and Roger Deslauriers.

Feedback improves accuracy performance

by Dave Malmquist
Accuracy Control Supervisor

During the past two months, thousands of measurements have been taken to test the accuracy of various assembly shipfitting processes.

An example of one of these processes would be how accurate can shipfitters align longitudinal beams to the plate edges. Each process has a design dimension and an allowable error factor called a tolerance. If the accuracy measurement falls within the tolerance, it is acceptable. If it falls outside the tolerance, it is defective and will probably require rework at a later stage of construction. Measurements are taken by one of the assembly table shipfitters or an Accuracy Control Checker.

Each week these measurements are analyzed, and the results of each assembly table are posted so shipfitters can see how they performed that week. This feedback of results is very important. The assembly table foreman and his fit-
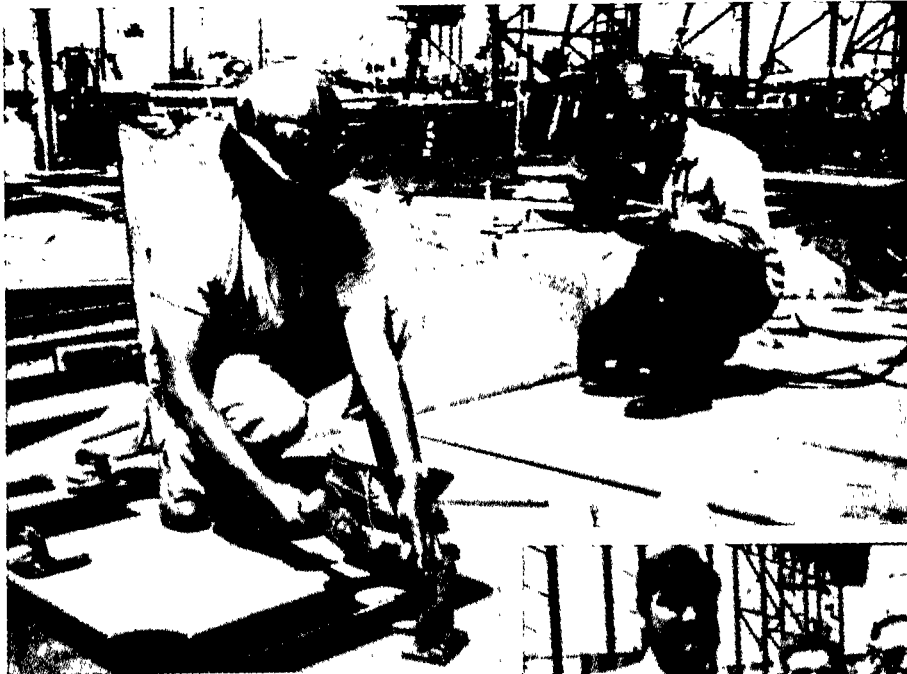
ters can readily see if their accuracy performance has shown improvement from the previous week's results. Analysis of the measurements sometimes reveals problems outside the shipfitters' control that are causing poor accuracy. Table discussion of accuracy results can also lead to suggestions from the fitters about how to improve the fitting process. Several jigs and fitting devices to improve accuracy have already been designed by table shipfitters.

Accurate fitting work means less rework at later stages of construction where the work becomes harder and more unsafe. Rework itself is a commitment to do the same work twice. By reducing rework, we can shorten construction time and reduce building costs. This makes us more competitive as a shipyard. It also will help our Company to bid more aggressively to secure new work in the future.

George Guerrero, shipbuilder, posts accuracy data on the Table 5/6 bulletin board as Mark Crawford, Accuracy Control analyst (far left), and Larry Rosene, fitting foreman, check the information.

Teamwork at Table 10

What's going on at Table 10 represent
another example of area teamwork an
cooperation.

At this Plate Shop location -which pro
vides assembled webs, floors, an
girders for the Exxon tankers–a grou
of fitters and welders, as well as a chip
per and a crane operator, work as a tear
under the supervision of Joe Escarcega
Code Welder Working Foreman.

The idea of placing the welders and fit
ters at Table 10 under single-trade super
vision originated in March '85 with Dav
Voigt, General Foreman, Fitting, an
Dave Walker, Foreman, Welding. "Tabl
10 seemed to be a good location to tr
this. Basically, this was the way the Com
pany was going. We thought we had th

(Above) Ben Fuentes, shipfitter, (left)
employs a re-usable dog to minimize
plate distortion (the dog was developed
by Table 10's ignacio Navarro and Pete
Castro) while welder Luls Torres pre-
pares to tack a member onto the as-
sembly. Teamwork between welders and
fitters at Table 10 has helped to elimi-
nate rework.

(Right) Enjoying a potluck lunch, the
Table 10 team includes (seated, from
left) Jose Murillo, Tim Plttrizzi, Frank de
la Cruz, Jorge Valdez, Fernando Ponce,
Luis Torres, Al Vasquez, Ray Johnson;
(standing) Dave Voigt, Sr., Joe Escar.
cega, Lou Mansfield, Jim Elkins, Ted Mc-
Callum, Minh Nguyen, Gabe Martinez,
Hung Cao, Dave Voigt, Jr,, Jorge Castro,
Phil Murray, Henry Posey, Ben Fuentes,
Aian Richle, and Cristobal Orozco. Not
present: Francisco Blas.

NASSCO Achievers

Measuring tool increases accuracy in web-frame fitting. In an effort to standardize the method of positioning and fitting stiffeners and brackets on web frames built at Tables 9, Francisco Herrera, a second-shift NASSCO shipfitter, designed a simple, but very effective, measuring tool that is now being widely used on Table 9 and 1. This measuring tool, which looks very much like a small carpenter's square, allows stiffeners and brackets to be consistently placed at the correct height above the cut-out longitudinal members. Francisco's measuring tool simplified the fitting process and reduces time spent refitting stiffeners that may have been tacked or welded in the improper position. The measuring tool has improved working conditions by making it easier to do the job, maintain good accuracy, and reduce rework.

Francisco's device is another example of a thoughtful employee with an idea that allows him to work smarter and more effectively.

Fitting aid reduces cutting, chipping, grinding. Javier Jiminez is a NASSCO shipfitter who developed a time-saving idea and converted the idea into a portable fitting aid that reduces the effort required to fabricate units in the weld-out area. Javier's fitting aid allows him to straighten stiffeners and move various unit components into position for welding with porta-powers and come-a-longs without having to weld clips to the steel plate and bulkheads involved. By lowering the number of welded clips that are required, Javier has simplified his job while also cutting considerably the extra time required to weld clips and then chip and grind off the scars.

NASSCO is very proud of Javier and the many other NASSCO employees who are continually seeking better ways to do their jobs. Javier's fitting aid is a perfect example of an employee who is "working smarter". He had a good idea that was converted into a tool/aid to make his job easier and less time-consuming.

"THE JIMENEZ CLIP"

APPENDIX C
DISCUSSION PAPERS

PAPER NO. **1** SUBMITTED BY DANIEL K. SILVERTON, PRESIDENT
FEDERAL EMPLOYEES METAL TRADES COUNCIL
VALLEJO, CA

Decentralization of Statistical Accuracy Control.

Although variations of the Statistical Accuracy Control process employed by NASSCO have existed in industry for many years, I have seen little literature regarding the process as related to the shipbuilding and repair industry.

What literature I have seen, leaned towards the belief that, unlike the Japanese worker, the American Blue Collar worker lacked the mathematical background necessary to implement a statistical accuracy control process. This belief is probably the result of two misconceptions.

One, of course, is the underestimation of the mathematical training received by trade/craft employees, particularly graduates of electrical and machinist apprenticeships. The second, and more important, misconception is the belief that statistical accuracy control need be a complex process beyond, absent extensive training, the average worker.

In implementing the process, NASSCO appears to have experiences and, to some extent, overcome the majority of the difficulties likely to be encountered in the process.

Certainly, the training of supervisors prior to the training of hourly workers, would improve the probability of success.

If practiced as an ongoing process, the need to retrain workers regularly should diminish as procedures became the normal mode of operation.

I do not see statistical accuracy control by ship production workers as totally replacing some form of 'quality control" function. There will always be a need to spot check the figures of those ship production workers performing the daily accuracy checks. I would, however, expect the process to result in a decline in the numbers of employees performing a solely quality control function. If coupled to an "error cause and removal" process, in a non-punitive manner, decentralization of the accuracy control function should result in reduced rework and increased employee productivity and, because of an increased sense of job control, increased employee morale.

PAPER NO. 2 SUBMITTED BY LAWRENCE W. KOZOYED, ASSISTANT VICE PRESIDENT
M. ROSENBLATT & SON, INC.
NEWPORT NEWS, VA.

The results of this paper are an important confirmation of the several principals of W. Edwards Deming as defined in his book Quality, Productivity and Competitive Position. Dr. Deming, a leader in showing the way to productivity improvements for the Japanese after World War II, is only now beginning to be recognized and heard in our country. The principles referred to which emerge as the underlying structure or framework for the project and enable it to be successful are as follows:

a. Productivity is highly impacted by quality. Improve quality and productivity will improve.

b. Top management needs to commit themselves to, and to work at, productivity improvements.

c. Dependence on mass inspection should be replaced with statistical evidence that quality is built in and then let the worker become involved in measuring it.

d. It is the job of management to find problems by working continually on the system.

e. Education and training need to be vigorously implemented.

f. Fear must be eliminated so that employees can work together effectively.

Any project which seeks productivity improvements with innovations in human resources needs a theory or statistical framework from which to proceed. Otherwise the project may become a "random walk" exercise in theory with success due only to the Hawthorne Effect. It is believed that any approach to innovations in human resources for productivity improvements will be improved if the Deming framework is reviewed and appropriately considered for the project. This project achieved its success by this approach.

The authors and the National Steel and Shipbuilding Company are commended for development of this research paper. The issue of accuracy control in the preventive rather than the appraisal (inspection) mode of product manufacture, although widely supported, remains an elusive element in the U. S. shipbuilding industry. The resulting reduced rework and improved productivity presented in the paper clearly illustrate the advantages of placing responsibility for quality on the first line supervisor and worker and not the Accuracy Control Department. It is unfortunate that the opportunity to continue the program did not exist and that the concepts developed were not exported to other functions in the Shipyard.

Participative management concepts, in the form of problem solving teams, multi-skilled and/or self managing work teams and other employee involvement (human resource) initiatives, are being more widely instituted in the shipyards; but the training and utilization of workers to insure quality is built into the products and services they provide is not being so broadly studied and applied.

The scope of the accuracy control program portrayed in the paper was somewhat limited in comparison to a total ship or shipyard operation. However, it did portray techniques to bring workers into the accuracy control business, and can be placed in all areas of ship production, including support operations. Engineering, planning, clerical and other work areas should be included in any quality improvement program to realize optimum quality improvement in the organization. This will also serve to eliminate artificial barriers between departments, offices and production functions where the need to communicate and cooperate in the resolve of quality problems is essential.

The paper outlined several steps found to be necessary that were put in place as the project was developed such as — management commitment, education and training, statistical measurement and charting, problem solving and employee feedback and recognition. The importance of proper development and implementation of these steps into the management and worker culture cannot be overemphasized. The two "noted consultants" cited in the report — Drs. Deming and Juran — and others (including Philip B. Crosby) propose that up to sixteen steps are vital to insure total, ongoing success in implementation of quality improvement in any organization. These steps bear on the technical (statistical) and philosophical (cultural) approaches that combine management support and worker participation in applying accuracy control in the work place. In the report, it was not clear that additional steps (i.e. those professed by the "consultants" listed above) had been considered or included during this project. It is suggested that they were not when stated that . . . "future and continued success of this program is not guaranteed".

Neverless, the paper has well achieved the purpose for which it was intended — to present the organizational structure and methods that if properly developed and implemented can decentralize the accuracy control responsibility to the ship production work force — with resulting improved quality (reduced rework) and reduced costs. This is not to say that installation of a sound quality improvement program or process is easy, it is not; and as described in the paper requires utmost support and commitment by all management levels (especially top management) to be fully successful.

More importantly, the paper illustrates a concept now used by foreign shipyards and other industries that can be put to work in U.S. shipyards which is an opportunity for substantial cost reductions that can no longer be disregarded. This message alone may be as valuable as the technical information presented in the report.